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Review of Electric Vehicle Developments, 1981

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ABSTRACT

A number of 1981 reports and news items are reviewed and correlated in this paper in order to link the life-cycle costs of the electric vehicle (EV) with its potential marketability. Recent test data show that the EV is currently more expensive to operate than the internal combustion engine vehicle (ICEV). The assessment of future markets will be modified by these results. Significant improvements are needed in battery performance and cost to enable the electric vehicle to reach a competitive level with internal combustion engine vehicles. The progress achieved in near-term battery developments is reviewed and assessed. Some governments appear to be de-emphasizing their financial support of electric passenger cars.

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1/ INTRODUCTION

This report is part of a series published annually, or as necessary, to summarize the more important developments in the field of battery electric road vehicles. These developments are selected from a large volume of recently published reports. The selection process is influenced by a need to present a sober assessment of current realities.

During this last year some interesting initial results have been produced by the U.S. DOE program on vehicle performance and batteries. As well, some useful studies have been done on the marketability of electric vehicles. A brief review of worldwide events in the past year which have a bearing on the future of the electric car is included.

2/ ELECTRIC VEHICLE PERFORMANCE AND LIFE-CYCLE COSTS

In its broadest sense, performance has two components. The first relates to how the vehicle fulfills, in a purely technical sense, the users' requirements. The second component, cost, is the one that provides a common reference point for the purposes of comparison. In the case of the automobile, this is usually expressed in total life-cycle cost (LCC) per unit of distance travelled in its lifetime.

2.1/ Performance

It was recognized early in the U.S. Department of Energy (DOE) program that the electric vehicle was a complex problem in system engineering. As a result of this, two contracts were placed with highly-skilled, resourceful U.S. companies to develop and build two cars per contract. These cars were to represent the best that could be done with applied systems engineering using present technology to produce an electric car which was comparable with a regular mid-sized car. The final result was two pairs of the most advanced electric vehicles available today, at a cost of about $3 million dollars each.

The first of these cars, designated Electric Test Vehicle - 1 (ETV-1), was built by the General Electric Company and the Chrysler Corporation for the DOE. This year the first set of independent tests on this vehicle were made available in a paper [1]. These tests were carried out by the Jet Propulsion Laboratories on a dynamometer. Set up to reproduce the measured road load conditions for the vehicle, this procedure allowed greater control over the tests than a road test would have.

The results presented in the paper were concerned with energy consumption and the vehicle ranges obtained are summarized in Table 2.

A constant speed test at 40 km/h (25 mph) was attempted, but the propulsion system was not designed for this wholly unrealistic mode of operation and the test has to be aborted due to controller overheating.

To some extent, all the constant speed tests tend to be unrealistic for an electric vehicle. Typical EV trips will usually feature a return to home base and involve city and urban driving patterns.

The D-Cycle test is a velocity time profile with about one stop per mile and is used to represent a typical driving pattern in city streets, where the EV is most likely to be used.

A previous similar J227a D-Cycle test carried out at a Chrysler test track apparently gave a range of 74.2 miles (119.7 km). It is noted in Reference 1 that seven differences in the test conditions may have contributed to the differences in range. Yet, most of these differences seem to be relatively minor and this points up the current difficulty in achieving reliable and repeatable data on vehicle range. The data also show that the range is very sensitive to the manner in which the vehicle is driven and tested.

The second of the optimized vehicles (the ETV-2) was developed by the Garret Corporation. This vehicle has a unitized body made from fibreglass-reinforced plastic to reduce weight and provide a long life. The propulsion system contains a flywheel to reduce the peak power drawn from the battery. This flywheel helps to extend the J227a D-Cycle range. The test results are not yet available for this vehicle, but its J227a D-Cycle range is expected to be longer than that of the ETV-1.

It should be pointed out that the ETV-1 is a greatly up-graded vehicle in all respects (except range) than previous electric vehicles. It was intended to be more like a regular car in acceleration, top speed and handling, and this has been achieved with an energy consumption 20% less than the lighter and smaller South Coast Technology (S.C.T.) electric Volkswagen Rabbit. However, the added power requirements necessary to obtain acceleration may have an adverse affect on the range. It is to be hoped that the ETV-2 flywheel will correct this problem.

It is unfortunate that no tests have been conducted or appear to be comtemplated on ETV-1 to establish the life of the battery under driving

conditions. As will be shown in Section 2, battery life is an important parameter.

The ETV-1 and -2 cars are, of course, prototypes.Therefore, it will not be possible to test them for life-cycle cost, since no reliable capital or maintenance costs are available for these cars as production models.

2.2/ Life-Cycle Costs

It is generally recognized that the high life-cycle cost of the electric vehicle represents a major barrier to their widespread use. Part of the U.S. DOE program is a Demonstration Project which is intended to provide data for potential users. The results of the data collected in these projects were presented in a paper at a recent conference [2]. Although the data are obtained from one test site, it is regarded by the authors as typical of many operations. The demonstation site and the vehicle identity are not disclosed in the paper. The data used to create Figures 1 and 2 and Table 1 of the present report are obtained directly from Figures 1 and 2 and Table 2 in Reference 2. The data have been re-arranged to illustrate that the effective cost of the electrical energy is much higher than the 2.4¢/km (3.86¢/mile) shown. All the other costs attributable to using electricity, 37.4¢/km (59.9¢/mile) in Figure 1, must be included to give the total effective energy cost of 39.8¢/km (63.7¢/mile). It is this low apparent cost of energy -- 2.4¢/km (3.8¢/mile) -- that is largely responsible for the prevailing misconception that EVs are more economical than internal combustion engine vehicles (ICEVs) (see Section 4).

If this grouping of costs is accepted, then Figure 1 shows that the effective cost of energy for the electric vehicle is 10.6 times that of the ICEV and also helps to identify and quantify the sources of the extra cost. The authors carried out a sensitivity analysis of the effect of changing the parameters and established the improvement targets shown in Table 1. The life-cycle costs are then reworked, assuming the targets are achieved. This gives rise to Figure 2, where the effective energy cost of the EV is over three times that of the ICEV.

These effective energy-cost ratios provide a very good measure of a possible major barrier to the marketability of the electric car. An electric car owner in the U.S. today is effectively volunteering to purchase energy at over ten times the cost of the gasoline he would purchase for a gasoline car. With projected improvements, this ratio may be reduced to only three times. However, Table 1 indicates that the improvements will not be attained easily as the battery appears to be the main culprit.

It should be noted that the cost of gasoline used in the above paper was equivalent to 42¢/L in Canadian dollars. A fuel consumption of 12 L/100 km or 23 miles per imperial gallon was used for the ICEV.

3/ MARKETABILITY

The recent revival of interest in electric cars was intially due to their potential as a means of reducing pollution from gasoline engine exhaust gases. The OPEC-inspired oil price increases of 1973 and since have further justified increased research and development to deal with possible oil shortages. During this period, it was shown that the EV could supply the needs of a restricted use-sector of the market place. In projecting the growth of the EV market, it was assumed that buyers would select a car which provided gasoline-free transportation, although it may fulfill only about 90% of the usefulness of a regular car. This approach tends to produce very optimistic estimates of the market.

In contrast to the above approach, the authors of two recent papers [5,6] have made a serious attempt to assess the attitudes of potential early EV adopters. In the first assessment [5], a number of people were selected from an upper-income suburb of Syracuse. These people were then invited to respond to a questionnaire on their attitudes towards electric vehicles. Seven vehicle parameters were used in the study with high, medium and low values (unfortunately, relative life-cycle costs were not included as a parameter).

Notwithstanding the limitations of the study, it was found impossible to obtain a favourable response to the purchase of an EV -- even when these parameters were made most beneficial. (For example, the cost was lowered to $5000 and the range was increased to 112 km per charge.)

The final conclusion was that the operational limitations of the EV would not rule out its purchase, but the price, in comparison with the ICEV, must be attractive. The fear of gasoline shortages does not appear to alter this finding. In effect, consumers regard the insurance premium of the extra cost as being too high in relation to the perceived benefits of assured mobility. It appears that the EV will have to offer significant economic advantages to overcome its lack of utility.

The second report [6] is the product of a company which periodically surveys the U.S. market to assess car-buying trends. This study, known as the Automotive Consumer Profile (ACP), examined the attitudes of 5000

American drivers on the considerations affecting their next car purchase. Table 3 shows the rankings obtained.

A comparison survey of EV owners showed that 29% considered saving money on gasoline or non-specific economy as the most important reason for buying an EV.

Combined with the ACP, a survey was conducted of prospective EV buyers given that a General Motors EV was available. Again, the leading reasons given were to save gasoline (19%) or save money (14%). Furthermore, it was found that the greatest degree of interest in the G.M. EV was found among owners of domestic sub-compacts (38%) and imports (39%). These owners obviously have a high interest in economy, if it is assumed that the purpose of saving gasoline is economy.

It is clear that there is a very strong perception on the part of would - be automobile purchasers that the EV is an economic car. This impression is possibly due to the tendency in the industry to stress the low cost of energy for the EV. Unfortunately, if the data in [2] are typical, then the common perception of EV economy may not be correct. On the other hand, although the survey of EV owners listed many complaints, lack of economy was not one of them. However, there is obviously some danger that the EV will fail to live up to levels of economy being suggested.

There is clearly a need for a more thorough marketing analysis where respondents are made aware of the realistic life-cycle costs to be expected from EVs. It is essential to carefully assess the potential of a mass market in order to exploit the potential benefits of mass production in getting the price of the EV down to a competitive level in relation to its limited utility.

4/ BATTERY PROGRESS

4.1/ Current Status

An important report on battery developments was presented in Reference 3. The U.S. DOE Electric Vehicle Battery project started in 1978 has reached a decision point where the most promising designs of batteries will be selected for continuing development. The candidate batteries were tested under carefully controlled conditions at the Argonne National Laboratories. The testing simulated the duty cycle imposed on the battery by the ETV-1 car by the SAE J227 D-cycle, and thus provides a measure of relative performance between batteries. The projected range data given in the paper were based on the energy-consumption data for the ETV-1, and are regarded as optimistic by the authors.

Figure 3 is reproduced from Reference 3 and illustrates some of the difficulties of meeting the total battery requirements. The nickel/zinc battery has the best specific energy but provides the poorest cycle life. The nickel/iron battery seems to be a very promising contender and deserves further consideration. Although its materials tend to be more expensive, the cost per cycle may be tolerable. A comparison of the cost per discharge cycle for these batteries would be a useful exercise.

The cycle life shown in Figure 3, however, needs to be translated into "on-the-road" cycle life. Reference 2 indicates an "on-the-road" cycle life of 110 for the lead-acid battery and this appears to correspond to a state-of-the-art laboratory cycle life of 250 [3]. The "on-the-road" life cycle, therefore, may be less than half of that shown. A similar translation is needed on the data range to get realistic data as Reference 1 indicates the ETV-1 range to be 70 km (44 miles), not 128 km (80 miles).

4.2/ Advanced Batteries

The batteries discussed in Reference 3 represent the near-term batteries. Many other advanced batteries are being considered and seem to be promising. These include the circulating electrolyte batteries such as the

Gulf & Western zinc chloride and the Exxon zinc bromine battery. While these new types promise larger capacity, greater range, and long life, they will also need large-capacity chargers. The zinc chloride battery needs 100 A at 220 V service in the garage for a full 8-h recharge. This could cause severe problems for electric distribution systems.

Another advanced battery is the aluminum/air battery which is recharged at about 1600 to 5000 km. This recharge is achieved by mechanical charging where the discharge by-product is removed and replaced with new aluminum plates. Many difficult problems remain to be solved with this battery, but it is believed that the energy cost to the car owner could be equal to that of synthetic gasoline [4]. This battery holds the promise of providing a larger range without the inconvenience of overnight charging and the need to invest in large-capacity chargers which affect the distribution system.

The ultimate success of the electric car will likely depend on an advanced battery of this type which permits mechanical recharging.

5/ BRIEF ITEMS OF INTEREST

CANADA

There are two significant programs being conducted in Canada. The first is the demonstration, test and development project on seven Marathon Vans which are being used by the operations and maintenance departments of the Seaway Transport Canada in St. Catharines.

A paper [7] was presented at the EVC Symposium VI describing the difficulties being encountered in the hostile winter environment. Electric heaters and thermal insulation were required to improve the storage capacity of the batteries. These tests are incomplete, but they have already identified significant opportunities for improving the design of the vehicle.

The second program, being managed by Ontario Hydro, is currently in its early stages and no results are available to date. This program will test electric vans and cars within the Ontario Hydro operation to permit an assessment of the action needed by the utility to respond to EV needs in the future.

U.S.A.

Significant cutbacks have occurred in the EHV Program as a result of Administration attempts to reduce government expenditures.

The Ford Company has launched an electric and hybrid vehicle development program. The nickel/zinc battery is favoured.

The G.M. program appears to have suffered a second postponement of its completion date. Former G.M. President Estes (who initiated the development) has indicated that the cost problems are proving to be very difficult.

Detroit Edison, a utility company, has set up a complete EV service station to service its fleet of 24 S.C.T. Volkswagen Rabbits. Sixteen of these vehicles are being leased to employees to test consumer reactions and attitudes.

A survey conducted by the Electric Vehicle Council in July, 1981, showed a decline in both back orders and manufacturing capabilities of 73% and 57%, respectively, over the previous year's survey.

Allied Corporation announced a breakthrough in batteries which use plastic electrodes. Their C & D Batteries subsidiary is developing this battery which holds out the promise of solving practically all the problems of EV batteries. However, the battery still needs to be charged electrically, and will require a high-capacity charger to active a long-range vehicle performance.

In an article in the Automotive News December 28th, 1981, Mr. Hemphill of J.D. Powers presented the results of a study into consumers' attitudes towards micro-mini cars. These results indicate a significant potential market for these vehicles and there is concern that the Americans will again find themselves playing catch-up with the Japanese in this new segment of the market. Consumers, it appears, are really stressing economy, and this is likely to retard the growth of the EV industry.

EUROPE

The U.K. government has swung support decisively to the commercial vehicle market. Government assistance is being made available to place many prototypes into service. Lucas and Chloride, who have now formed a combined company, are exploiting this opportunity identified by their research work. This activity is justified by projected improvements in the manufacturing economics of these vehicles and on the expectation that fuel costs will continue to rise significantly, over and above inflation. There is, however, no significant government support for electric passenger cars. However, low-level activity has started on hybrid cars, which use both batteries and gasoline, to overcome the range limitations.

In the U.K., it has also been found that the life-cycle cost of the electric vehicle is very dependent on the degree of misuse it suffers. Lucas Chloride are proposing to use a micro-processor to control the loading and charging cycles of the battery so that the operator cannot damage the battery. This idea may lead to significant improvements in EV performance.

The West German government issued a study which recommends that it not support the commercialization of battery vehicles. The study indicated that even with production figures of 50 000 vehicles/yr, the purchase price of an EV would be twice that of a comparable ICEV. The report recognizes the lead-acid battery as the most realistic battery and also recommends continuing support for battery research.

A leading German company, G.E.S., has converted a Volkswagen Rabbit to electric, and its city driving range is 51 km (32 miles). They propose building ten vehicles for the purpose of testing.

JAPAN

Recent reports indicate that the Japanese government has reduced its goals for electric-vehicle production and is now relying on private enterprise for research and development efforts.

The previously-announced goal of 250 000 on-road vehicles by 1986 is being revised to a substantially lower figure. Apparently, present EVs on Japanese roads comprise 200 commercial vehicles and 40 passenger cars.

6/ SUMMARY

This report has reviewed published papers and reports made available in 1981 with a view to assessing the barriers to extended use of EVs. The papers selected were chosen from a vast quantity because they appear to be realistic in themselves and present findings which are complimentary to, and reinforce, the other selected papers. Thus, performance and life-cycle costs are closely coupled by the manufacturers. They are also closely coupled in the mind of the consumer, as revealed by the marketing studies. A problem arises, however, when the marketing studies are carried out on consumers who may not appreciate the implications of the hidden energy-related costs of the EV. As it happens, the marketing studies appear to show that the consumer is still not enthusiastic about EVs.

It is possible that the knowledge that the effective energy cost of an EV is many times that of the competing ICEV, may be a significant disincentive for many would-be EV purchasers.

The progress being made in the battery development is slow. It would be unrealistic to expect any significant change in the effective energy cost ratios in the near term.

There are also signs that governments throughout the world may be de-emphasizing their financial support for passenger EVs. Many will suggest that this review paints a gloomy picture of EV prospects; however, there exists a real danger that the EV will fail because it may not live up to its currently undeserved reputation for economy. If the industry does not deal realistically with this problem, then the electric car may once again be interred.

A final quote from a proponent of EVs may serve to reinforce the need for realism:

> "It seems this industry is plagued by a liberal sprinkling of cloudy-eyed seers who pop up periodically to predict highly unlikely achievements for the EV industry... It seems to us that even-handed realism might guide the industry in a more beneficial manner...

> The growth (of the industry) at times may be agonizing -- but it is real...
>
> Now is the time for stark reality. It wil be the fulfillment of needs that eventually will enrich the history of EV growth in the years ahead."

[Author's Italics. Electric Vehicle News, August 1981, Page 1, Editorial.]

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[7] Andres, D.G., "The Canadian Federal Government Program For Evaluation and Development of Electric Vehicles," Proceedings of EVC Symposium V1, Baltimore, MA., October 21-23, 1981. Paper No. 8157.

Table 1/ Observed and Target Values of Key EV L.C.C. Determinants

	Observed	Target	Ratio
Battery Life (Cycles)	110	300	2.73
Useable EV range in miles/charge (km/charge)	25 (40)	35 (56)	1.4
Annual use of EV in miles/ year (km/yr)	6000 (9677)	9100 (14 677)	1.5
Maintenance in h/1 000 miles (h/1613 km)	88	35	0.4
Tax Credit (% of purchase price)	10	25	2.5

Table 2/ Energy Consumption and Vehicle Range

Speed	Range
56 km/h (35 mph) constant speed	96.7 miles (156.0 km)
72 km/h (45 mph) " "	72.5 miles (116.9 km)
88 km/h (55 mph) " "	57.1 miles (92.1 km)
SAE J227a D cycle	44.3 miles (71.5 km)

Table 3/ Most Important Consideration in New Car Purchase

Fuel Economy	33%
Dependability	24%
Low Price	11%
Safety	8%
Quality of Workmanship	4%

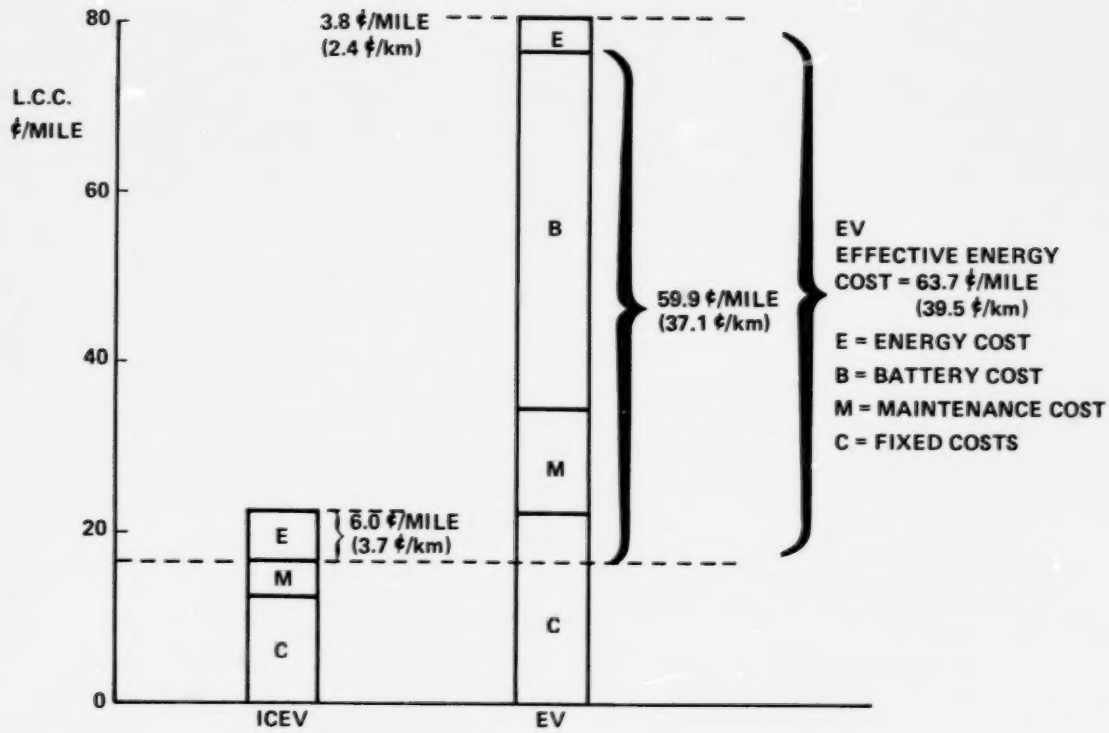

Figure 1/ Observed Life-Cycle Cost Based on 6000 Miles/Year (9677 km/Year)

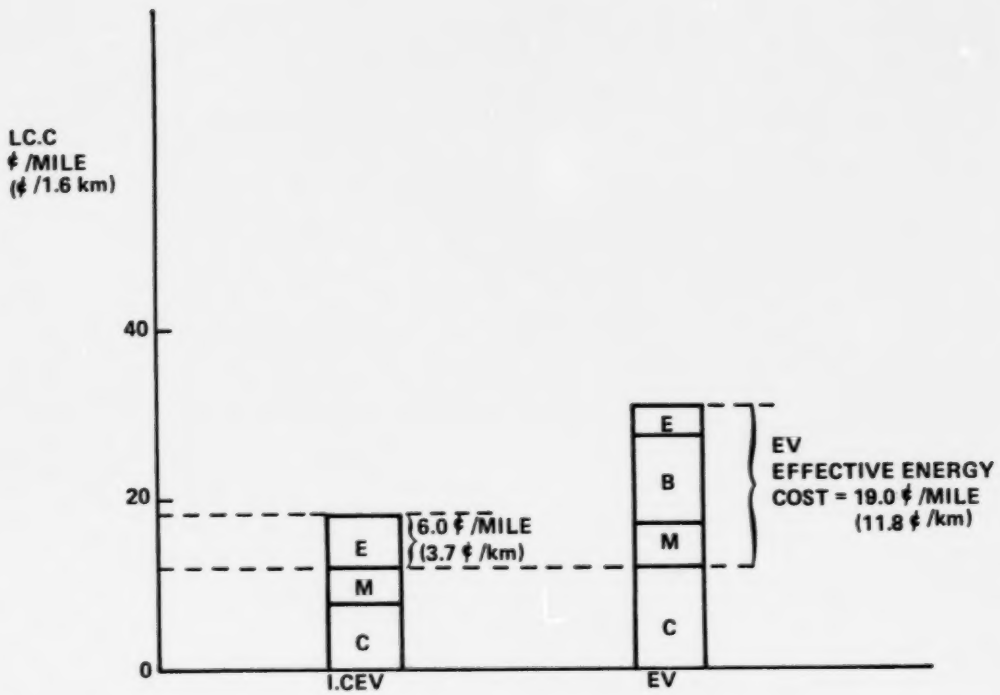

Figure 2/ Targeted Life-Cycle Cost

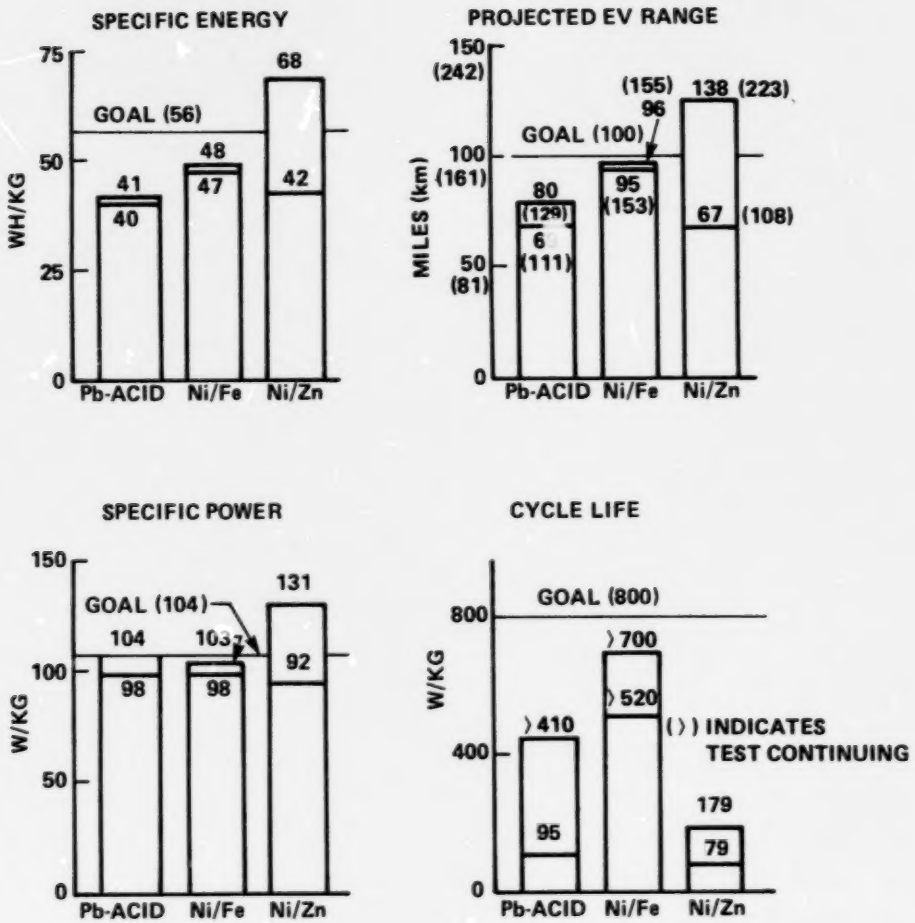

Figure 3/ Performance and Life of Improved Electric Vehicle Batteries as Measured at the ANL National Battery Test Laboratory as of August 10, 1981 (from Reference 3)